PLANETARY MISSIONS FROM GTO USING EARTH AND MOON GRAVITY ASSISTS*

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ABSTRACT

A general method has been developed which permits the transfer of a spacecraft from a highly elliptic and specifically oriented orbit to a general escape direction and energy. Also, the method is flexible enough to allow a several month launch opportunity. An application currently being considered by JPL is launch of secondary payloads to Mars and other destinations from the Ariane geosynchronous transfer orbit (GTO). The GTO orbit is highly constrained to have a 7 degree inclination to the Earth's equator, and an apogee arrival at noon local time. The velocity cost to provide this enabling capability is 100 to 300 m/s above that required if the same elliptic orbit were ideally oriented and the maneuver were done at perigee, for the escape direction required.

This method, referred to here as Moon-Earth gravity assist (MEGA), requires that three major maneuvers be done at specific places which, together with one lunar swingby and one Earth gravity assist, results in four trajectory segments. An example shown in the Figure, which is a Mars 2003 mission, illustrates the method.

The top and middle illustrations are the same, where GTO launch is Feb. 17, 2003, the first available launch date. For this early launch, the spacecraft, after release from the Ariane, remains in GTO until March 29, 2003, when it injects, in-plane and at perigee, to an apogee distance of 1,300,000 km. At apogee, 30 days later, a second maneuver is made to allow encounter with the Moon on a predetermined day and time, which is a few days before a direct launch from Earth to Mars would normally be made.

At the Moon, 30 days later, a lunar swingby is performed such that the spacecraft returns to the vicinity of Earth (at a specified 300 km altitude) to do a third burn at perigee which will allow it to escape Earth on the required date of May 31, 2003, and with the proper escape direction and energy. The only penalty in this case over a single direct burn on this date is the deep space maneuver of 180 m/s, plus any navigation requirements.

In the bottom illustration, for the last GTO launch opportunity, May 3, 2003, the same procedure applies. But now, there is no waiting in GTO, and the apogee distance is only to 750,000 km. The penalty here is 220 m/s. Again, the third burn at Earth is made on May 31 as it was for the February launch, and escape is in the desired direction as shown in the figure.

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This procedure allows a launch period of 75 days for the Ariane, without disturbing their launch requirements for delivering communication satellites to GEO. If, however, some flexibility exists for the high noon apogee constraint, the launch period can be significantly enlarged. For example, the launch period can be backed up into January if the apogee arrival time could be moved to 2 p.m. local time instead of noon.

In the paper, more detailed explanation of the MEGA launch method will be given, along with the details of the computer program written to directly compute these four-segment trajectories. Solar perturbation effects are included in the calculation of the segments which extend beyond the Moon. For Venus, and other inner bodies, a double lunar swingby is sometimes required. Graphical results will be included for the upcoming Mars and Venus opportunities and general mission design charts for other targets will be included in the paper. Finally, limitations of this method will be described, and alternate but related methods will be suggested.

REFERENCES

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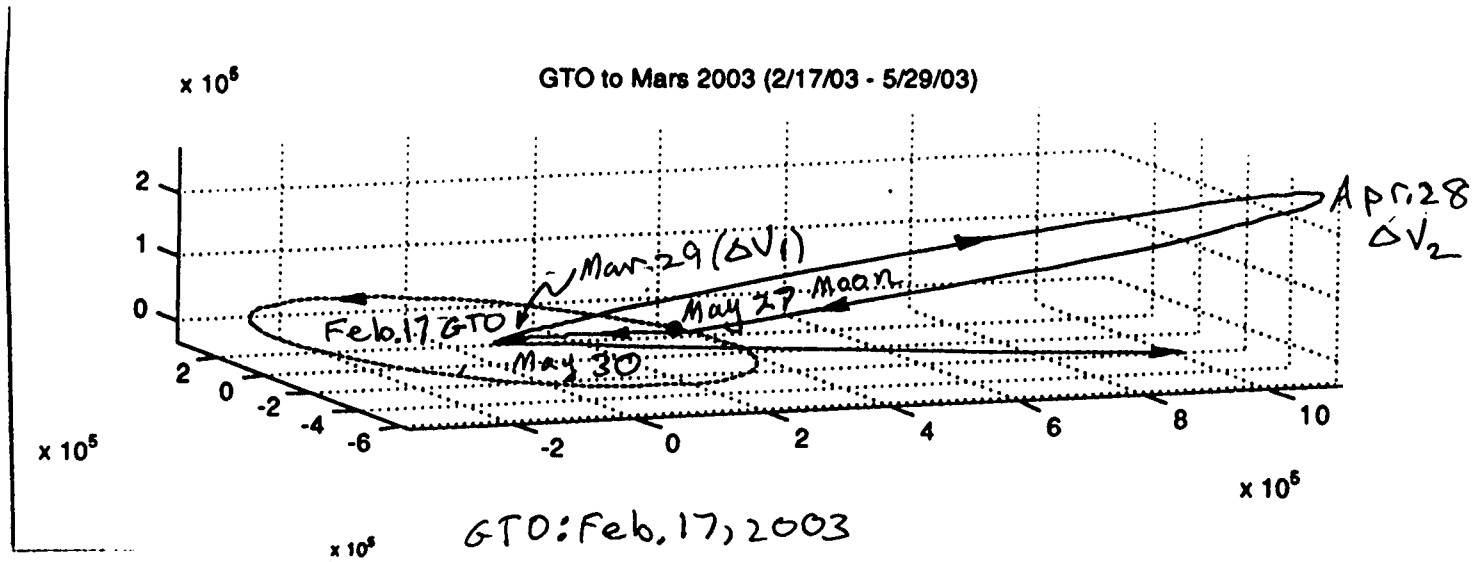

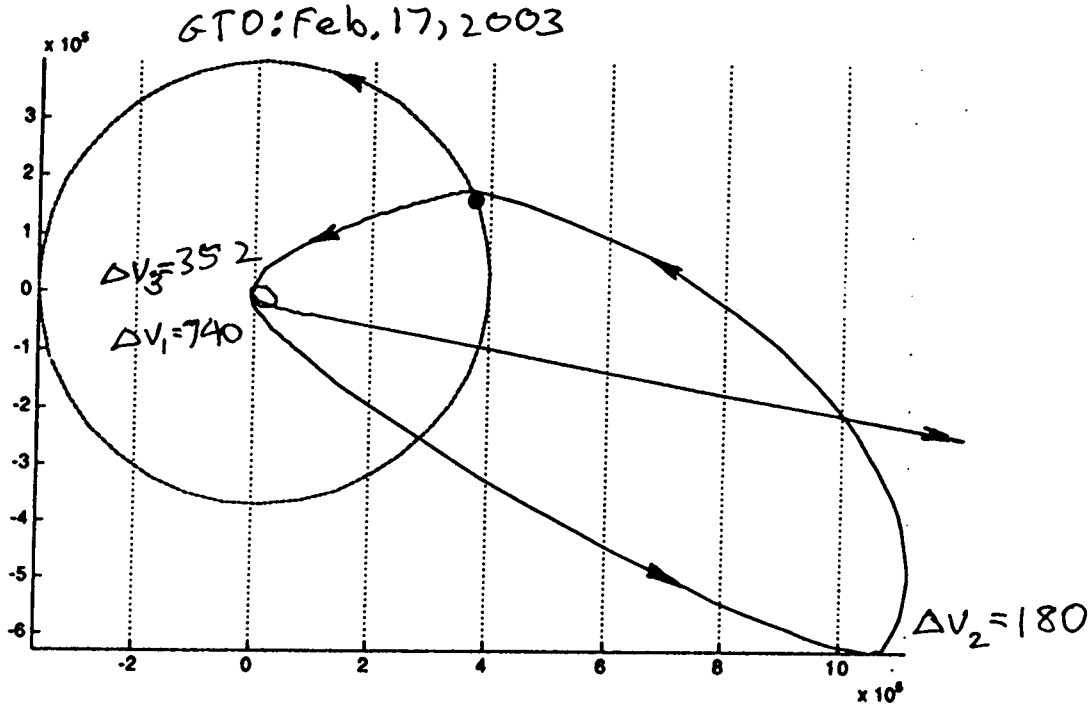

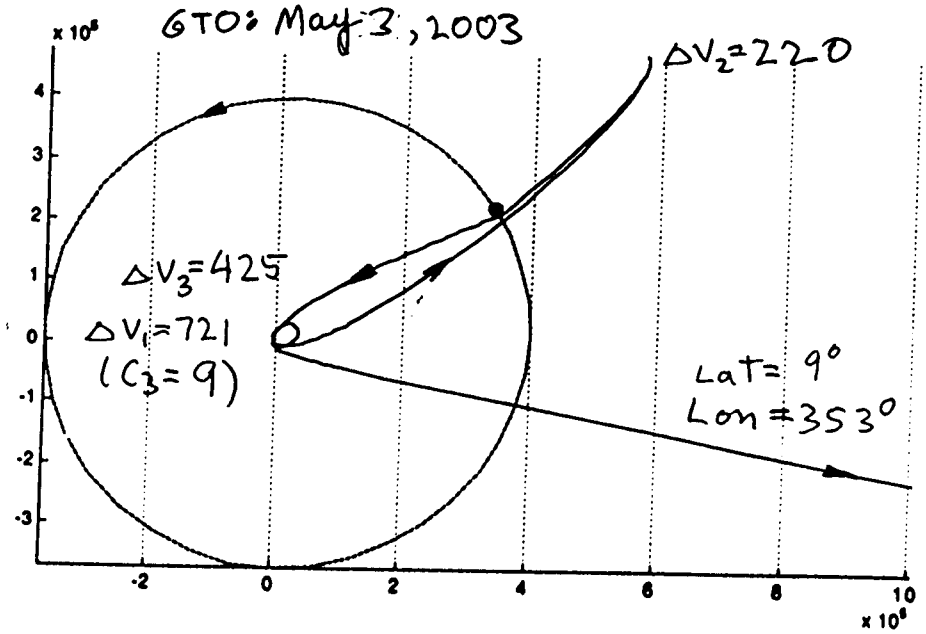

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